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Bridge Deck Deterioration

Panel Discussion

"Designing for Durability"

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Design for Prevention of Deterioration

or

Designing for Durability

After hearing from the other panel members on Factors Causing Deterioration and Field Evaluation for Remedial Measures the next step is to utilize this knowledge in the development of design guides to prevent deterioration.

In any design it is necessary to have or to know what loads, forces, environment and other factors that you must design for. The principal external load to be applied to a bridge deck is the live load resulting from a moving truck wheel. Bridge designers have not always used heavy enough wheel loads for bridge decks. A large increase was introduced in the 1959 AASHO bridge specifications when the design wheel loads were effectively increased from 12,000 pounds to the present 16,000 pounds. The distribution reinforcement was also increased by the 1961 design specification changes. These two changes, increased wheel loads and greater percentage of distribution reinforcement, has resulted in almost a two fold increase in the longitudinal reinforcement in highway bridge decks.

These design changes have produced stronger bridge decks and, I am sure, have resulted in increased service life. Here in California a deck crack research report[1] on the Webber Creek

1. California Division of Highways, "Webber Creek Deck Crack Study," Final Report, March 1972, CA-HWY-BD-624102(2)-72-2.

Bridge concluded that, "The amount of longitudinal distribution reinforcing steel has a greater effect on inhibiting the formation of leaking cracks than does either cement type or aggregate type."

The largest quantity item used in bridge deck construction is concrete. What role does quality concrete play in bridge deck durability? The excellent and comprehensive report published by the Portland Cement Association[2] contained a number of recommendations for obtaining improved durability. The recommendations concerning quality of the concrete are summarized in Table 7 of the report.

Table 7. Recommendations for Quality Concrete for Bridge Decks

Max. size of coarse aggregate, in.	Max. water-cement ratio		Min. cement content		Air content, percent (± 1 percent)	Max. slump, in. (± ½ in.)	Min. 28-day compressive strength, psi*
	Gal. per bag	Lb. per lb.	Bags per cu.yd. of concrete	Lb. per cu.yd. of concrete			
In areas where de-icers are used							
½	5.0	0.44	7.6	714	8.0	2½	4,500
¾	5.0	0.44	7.0	658	7.0	2½	4,500
1	5.0	0.44	6.6	620	6.0	2½	4,500
1½	5.0	0.44	6.2	583	5.5	2½	4,500
In areas where de-icers are *not* used							
½	5.5	0.49	7.0	658	5.5	2½	4,000
¾	5.5	0.49	6.4	601	5.0	2½	4,000
1	5.5	0.49	6.0	564	4.5	2½	4,000
1½	5.5	0.49	5.6	526	4.0	2½	4,000

*No more than 20 percent of the strength tests should have values less than indicated here.

2. Portland Cement Association, "Durability of Concrete Bridge Decks, Final Report, A Cooperative Study," 1970.

Concrete produced under these specifications can be called good quality concrete. If we examine the ingredients of good quality concrete, we see that for the suggested 1" maximum size aggregate, they are low water-cement ratio (0.44 pound per pound), high cement factor (6.6 bags per cubic yard), 6% air content and low maximum slump (2-1/2"). Such a mix should be expected to produce minimum 4,500 p.s.i., 28-day compressive strength. This is a far cry from the all too often, normal, 3,000 p.s.i., high slump concrete which is used by many highway departments for the construction of bridge decks.

From the research previously reported in Dick Hay's talk[3], we have been made aware of what deicing salts do to good quality concrete. To my satisfaction, his research does more to clarify the distressing performance of concrete bridge decks than any other investigation conducted to date. As bleak as the present picture of bridge deck durability is, the research findings also provide a glimmer of hope. Now that the culprit has been identified, improved design procedures must be called upon.

Knowing how deicing chemicals can penetrate into the good quality concrete (1" penetration with only 7 applications) and knowing what these chlorides can do to the unprotected steel, one solution is to make the reinforcing steel inert to chemical attack, such a design is shown in Figure No. 1.

3. K. C. Clear and R. E. Hay, "Time-to-Corrosion of Reinforcing Steel in Concrete Slabs," Volume 1, April 1973, Report No. FHWA-RD-73-32.

Inert Coating

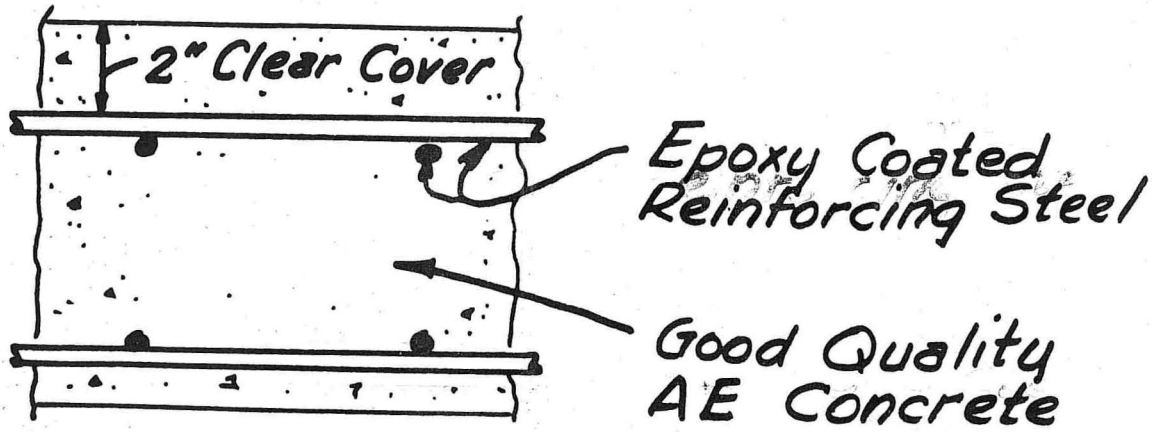


Figure 1

The successful performance of this design depends upon the scaling resistance of the good quality concrete and the non-corrosion of the reinforcing steel. The short comings of this design is the lack of service experience of epoxy coated reinforcing steel and the excessive cost to date. While we anticipated installed cost of epoxy coated bars to be not more than $.40 per pound, some bid prices have been about 50% more than this amount. The lowest known bid has been $.45 per pound, but this represents only about 6 actual

bids. We still have high hopes for this material as a permanent solution to the corroding steel problem. With this material there is still the need for high quality "non-scaling" concrete. That is the reason that air entrainment is shown.

The design most relied upon for durability has as its main ingredient a waterproof membrane and an asphaltic concrete wearing course. The main features of this design is shown in figure 2:

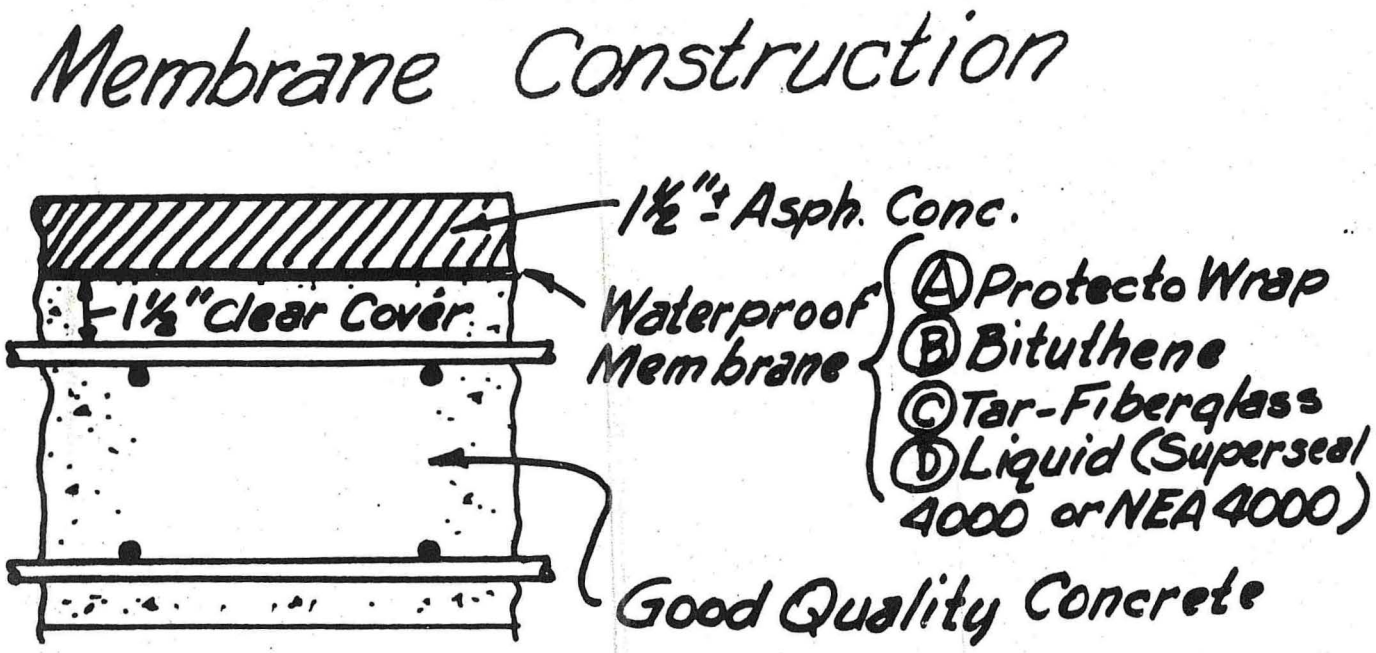


Figure 2

This is the design or similar designs considered to be standard by many highway departments and is the standard practice in most European countries. Experience has shown the necessity for a heavy 65 pound building felt or similar material over the liquid membranes. Similar cover is also recommended for the Protecto Wrap and Betuthene membranes. These soft membranes have a tendency to shove under heavy stopping traffic and are not suitable for structures on steep grades.

In the PCA report[2], previously referred to, there was a strong recommendation for further research on Two Course Bonded Construction. Dick Hay's report has shown the wisdom of the earlier recommendation and a two course design is illustrated in figure 3.

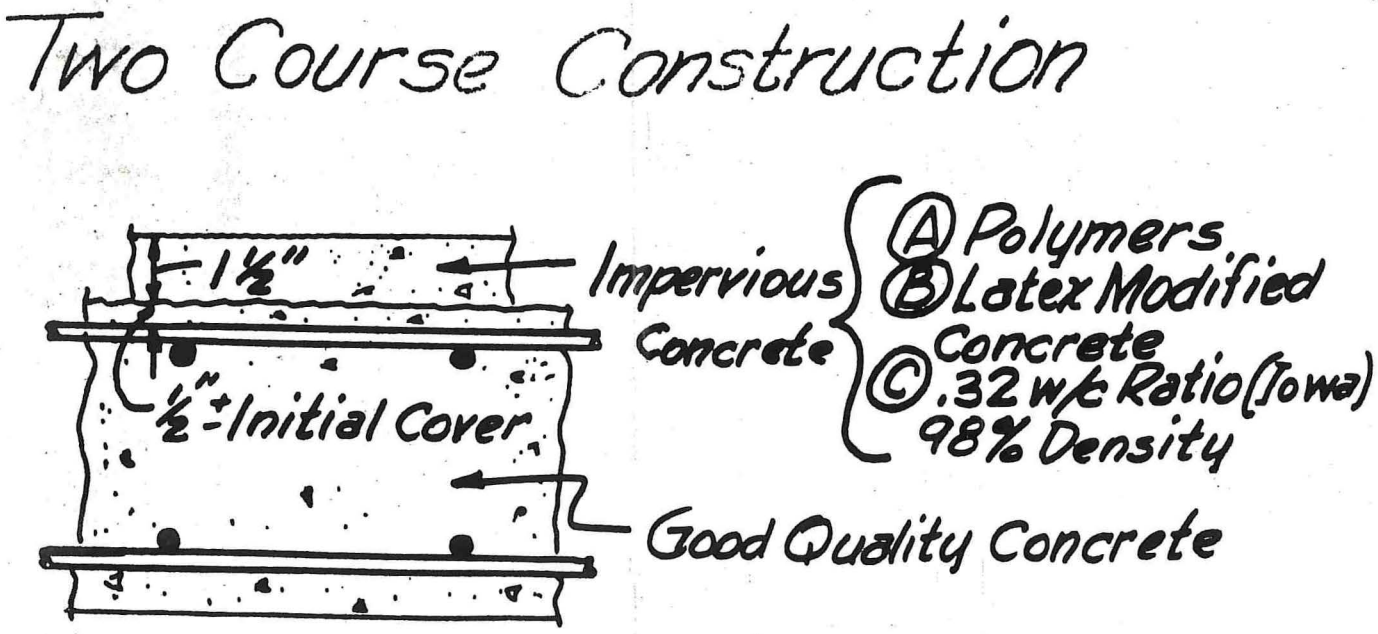
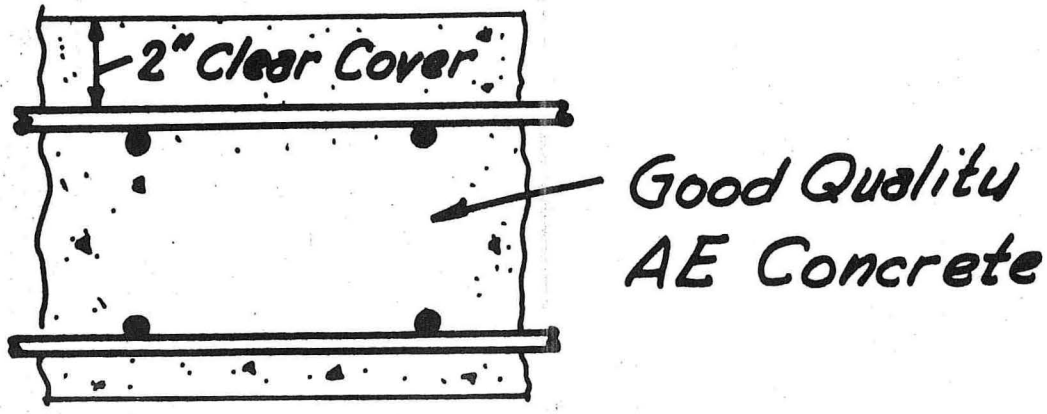


Figure 3

The secret of satisfactory performance of this design is the relatively impervious concrete in the top course. The use of polymers in concrete bridge decks can only be considered to be in the experimental stage to date. It should also be pointed out that both the latex modified concrete and the Iowa system concrete have shown some, but not dangerous amounts, of chloride penetrations in laboratory tests and in full scale construction.

The last design, figure 4, is good only in areas where deicing chemicals are not used, and where there is no salt or brackish waters nearby. In this design the structure should be designed to carry a future membrane and wearing course in the event salting will be used.

Standard



No Deicing Chemicals
Nor Salt Water Environment

Figure 4

A number of other designs and materials have been used in bridge deck construction and have not been mentioned in the above recommendations. It is my judgment that they have doubtful value for bridge deck durability. I will discuss a few of these and will give my reasons for not recommending them in this paper.

1. Three inch cover of "good quality" concrete. No doubt you can buy additional time before the bridge deck will corrode. I do not believe that the additional dead load and cover is cost effective.

2. Galvanized reinforcing steel. Certainly limited experimentation should continue with this product, but with our knowledge of chloride penetration into concrete and the sacrificial nature of the zinc protection, eventual spalling of the concrete is a real possibility.

3. Cathodic protection of the steel reinforcement. Dick Stratfull's installations show encouraging results but long term service performance is lacking

This talk would not be complete without some reference to other design details that I will briefly mention. (1) Proper and effective joint sealing systems are essential to avoid damage to unprotected superstructure and substructure. (2) Adequate drainage of surface water and at inner layers of membrane designs are very important.

Even though one of these designs or possibly others may emerge as the foolproof, 100% guaranteed perfect design for durability

we must never lose sight of the importance of quality construction and the many pitfalls of negligence in proper material and construction controls.